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Procedure for Coordinates Conversion between NTM and UTM Systems in Minna Datum Using AllTrans and Columbus Software

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ABSTRACT

As the Edo State Branch of the Nigerian Institution of Surveyors (NIS) has decided to align with the agency (Edo Geographic Information Service) that is responsible for the processing of Certificate of Occupancy to be determining positions in the UTM system, the coordinates of the existing controls in the State have to be converted to UTM coordinates using conversion software. Consequently, this paper presents detailed procedures for the application of AllTrans and Columbus software for positions conversion between NTM and UTM systems in Minna datum. The Minna datum properties, as well as the NTM and UTM parameters, have been detailed for effective use. The step by step procedures to consider when applying the software have enumerated. It was recommended that the Edo State branch of the institution (NIS) should get the full and the latest version of the software. It was also recommended that there should be a lecture for the practical demonstration of the detailed procedures.

Keywords: Coordinates, Conversion, NTM, UTM, AllTrans, Columbus, Software, Minna Datum, Clarke 1880

I. INTRODUCTION

The Edo State Government of Nigeria has established an agency responsible for the processing of Certificate of Occupancy. The agency known as the Edo Geographic Information Service uses orthophotos for positions determination. The orthophotos were georeferenced with Universal Traverse Mercator (UTM) coordinates in Minna datum. Thus, the positions determined by the agency using the orthophotos are in UTM. The system does not have a frame to realize it in the State.

Over the years, positions of points have been determined in the State by Surveyors in the Nigeria Traverse Mercator, NTM (state plane) which is also known as the National Origin. These two systems (NTM and UTM) are rectangular coordinate systems measured in linear metres. But they are different in origin and scale. The processing of a Certificate of Occupancy requires the use of a survey plan produced by a Registered Surveyor. Presently, Surveyors in the State are producing survey plans with respect to the National Origin (NTM) while the agency is checking/charting the positions determined in NTM by the private practising Surveyors using their (the agency) system designed to determine positions in UTM. Checking/charting the NTM coordinates by the agency with its system requires the conversion of the NTM positions to UTM coordinates. Consequently, the Nigerian Institution of Surveyors, Edo State Branch has decided to be determining positions in the State in the UTM system to align the agency. To do this, the NTM positions of all the existing control stations in the State must be converted to UTM positions of the same controls. This is necessary as any

survey carried out must be connected to as well as oriented with not less than three control stations. The switching from NTM to UTM position determination by the Institution was discussed in its meeting held on 1st June 2019, but the final decision is yet to be conveyed to the respective state surveyors. The conversion of positions in a rectangular system (NTM or UTM) to another rectangular system (NTM or UTM), requires the coordinates to be first converted to geographic coordinates then from geographic coordinates to the positions of the points in any other rectangular coordinate system of interest. Also, from the geographic coordinates, the geocentric coordinates (XYZ) of the points can be determined. It is to be noted here that since the conversion is within Minna datum, transformation/datum shift parameters are not needed. Datum shift parameters are needed when transforming between two datums say WGS 84 and Minna datums.

To convert coordinates from one rectangular coordinate system to another, transformation /conversion software is used. Consequently, this paper presents detailed procedures for the conversion of positions from one rectangular coordinate system to another using AllTrans and Columbus software. These software have been compared with other transformation/conversion software and recommended for application in Nigeria. The comparison of the software is detailed in Eteje *et al*. (2018). For effective application of the two conversion software in Edo State as well as the entire country, the properties of the Minna datum, the NTM projection (the three belts parameters) and those of the UTM projection (the three zones parameters) must be known. Also, the extent/bound width of each belt and zone in each state must be known. This will enable the belt and the zone which the positions to convert be identified before conversion. Edo State is partly west and mid belts, and partly zones 31 and 32.

1.1 AllTrans Software

According to George (2012), use the AllTrans application to perform coordinate transformations between various coordinate systems. As mentioned above, one can perform conversions between coordinates using different mathematical representations and geodetic systems. One can perform transformations between Gauß-Krüger coordinates, UTM coordinates, geographic coordinates and 3D-Cartesian coordinates. Manually input the data or import it to perform the transformation. With AllTrans software, 7-Parameter Datum Transformation and calculation of datum transformation parameters using identical points can be carried out.

1.2 Columbus Software

Columbus is a one, two, and three dimensional network adjustment, network pre-analysis and coordinate transformation software package which allows one to create, edit, solve and analyse Vertical, Geodetic, State Plane, UTM, Custom Projection and Local NEE (North, East and Elevation) surveys anywhere in the world (Columbus, 2009). Columbus accepts terrestrial and/or GPS (satellite) observations to define networks. Columbus is not just a network adjustment package; it is a complete toolkit which can be used for on-the-fly COGO computations, coordinate transformations, geoid modelling and computation of areas of selected polygons in a project. According to Columbus (2009), to report coordinate results in a different form, Columbus provides a powerful set of coordinate transformation tools to generate Geodetic, State Plane, UTM, Custom Projection, Earth Centred Earth Fixed Cartesian, or Local North, East and Elevation (NEE or NEU) positions. To transform geodetic positions from one datum to another, Columbus provides rigorous three, four and seven parameter least squares datum transformation capability. Columbus also includes an assortment of Geodetic, State Plane, UTM, Local NEE

coordinate geometry (COGO) routines for ad-hoc computations, network loop closure and open-ended traverses.

1.3 The Nigeria Geodetic Datum

According to Eteje *et al.* (2018), the Nigeria Minna datum is a geodetic datum that is suitable for use in Nigeria-onshore and offshore. Minna datum references the Clarke 1880 (RGS) ellipsoid (Semi-major axis, a = 6378249.145m; Flattening, f = 1/293.465) and the Greenwich prime meridian. The datum origin is a fundamental point: Minna base station L40. Latitude: 9°38'08.87"N, longitude: 6°30'58.76"E (of Greenwich). It is a geodetic datum for topographic mapping. It was defined by information from NIMA (Eteje *et al.*, 2018). Uzodinma *et al.* (2013) gave the orthometric height, H of station L40 as 281.13m.

1.4 Conversion of NTM and UTM Northing and Easting Coordinates to Geodetic Coordinates (φ, λ, h)

The conversion of the two rectangular systems (NTM and UTM) coordinates to geographic positions, requires the application of the same models. The systems only differ in origin and scale factor. The models for the conversion of the NTM and UTM coordinates to geodetic or geographic coordinates as given by Kiliç, (2005) are:

$$\varphi = fp - Q_1(Q_2 - Q_3 + Q_4) \quad (1)$$

$$\lambda = \lambda_o + (Q_5 - Q_6 + Q_7)/\cos(fp) \quad (2)$$

Where,

$$Q_1 = N_1 \tan(fp)/R_1 \quad (3)$$

$$Q_2 = D^2/2 \quad (4)$$

$$Q_3 = (5 + 3T_1 + 10C_1 - 4C_1^2 - 9e'^2) D^4/24 \quad (5)$$

$$Q_4 = (61 + 90T_1 + 298C_1 + 45T_1^2 - 3C_1^2 - 252e'^2) D^6/720 \quad (6)$$

$$Q_5 = D \quad (7)$$

$$Q_6 = (1 + 2T_1 + C_1) D^3/6 \quad (8)$$

$$Q_7 = (5 - 2C_1 + 28T_1 - 3C_1^2 + 8e'^2 + 24T_1^2) D^5/120 \quad (9)$$

$N_1 = a/(1 - e^2 \sin^2(fp))^{1/2}$ (Radius of curvature in prime vertical) (10)

$$R_1 = a(1 - e^2)/(1 - e^2 \sin^2(fp))^{3/2}$$

(Radius of curvature in meridian section) (11)

$$D = x/(N_1 k_o) \quad (12)$$

$$C_1 = e'^2 \cos^2(fp) \quad (13)$$

$$T_1 = \tan^2(fp) \quad (14)$$

$e'^2 = (ea/b)^2 = e^2/(1 - e^2)$ = Second eccentricity squared (15)

$e^2 = (a^2 - b^2)/a^2$ = First eccentricity squared (16)

$$fp = \mu + J_1 \sin(2\mu) + J_2 \sin(4\mu) + J_3 \sin(6\mu) + J_4 \sin(8\mu)$$ = Footprint Latitude (17)

$$\mu = M \Big/ \left[a(1 - (e^2/4) - (3e^4/64) - (5e^6/256)...) \right] \quad (18)$$

$$M = y/k_o \quad (19)$$

$$e_/ = \left[1 - (1 - e^2)^{1/2}\right] \Big/ \left[1 + (1 - e^2)^{1/2}\right] \quad (20)$$

$$J_1 = \left[(3e_/2) - (27e_/^3/32)..\right] \quad (21)$$

$$J_2 = \left[(21e_/^2/16) - (55e_/^4/32)..\right] \quad (22)$$

$$J_3 = (151e_/^3/96..) \quad (23)$$

$$J_4 = (1097e_/^4/512..) \quad (24)$$

$a =$ Semimajor axis

$b =$ Semiminor axis

k_o = Scale Factor (0.9996 for UTM and 0.99975 for NTM)

x = Easting Coordinate (relative to the Central Meridian, CM: (subtract the CM from conventional UTM coordinate, *x;* 500,000mE for UTM while it varies for NTM, west belt = 230738.266mE, mid belt = 670553.984mE and east belt = 1110369.702mE).

y = Northing Coordinate.

1.5 Conversion of the Geodetic Coordinates (φ, λ, h) to Plane Rectangular Systems (NTM and UTM) Coordinates

The models for the conversion of geodetic coordinates to either of the two local plane rectangular (NTM or UTM) coordinates are the same. The differences in the two plane systems are in the properties to be used in the conversion. Thus, the origin, and scale factor. To convert the geographic coordinates (latitude and longitude) on the local ellipsoid to either NTM or UTM northing and easting, equations (25) to (34) given by Manchuk (2009) are used.

$$E = k_o N \begin{bmatrix} A + (1 - T + C)A^3/6 + (5 - 18T + \\ T^2 + 72C - 58e'^2)A^5/120 \end{bmatrix} \quad (25)$$

$$N = k_o \begin{bmatrix} M - M_o + N\tan\varphi[A^2/2 + (5 - T + \\ 9C + 4C^2)A^4/24 + (61 - 58T + T^2 + \\ 600C - 330e'^2)A^6/720] \end{bmatrix} \quad (26)$$

$$k = k_o \begin{bmatrix} 1 + (1 - C)A^2/2 + \\ (5 - 4T + 42C + 13C^2 - 28e'^2)A^4/24 + \\ (61 - 148T + 16T^2)A^6/720 \end{bmatrix} \quad (27)$$

Where,

$k_o = 0.99975$ for NTM and 0.9996 for UTM (28)

$e'^2 = e^2/(1 - e^2)$ = Second eccentricity squared (29)

$e^2 = 2f - f^2$ eccentricity squared (30)

N = Radius of curvature as given in equation (2)

$T = \tan^2\varphi$ (31)

$C = e'^2\cos^2\varphi$ (32)

$A = (\lambda - \lambda_o)\cos\varphi$ (33)

N = Northing of point.

E = Easting of point.

φ = Latitude of point

λ = Longitude of point

λ_o = Longitude of point of center meridian of belt or zone.

$$M = a \begin{bmatrix} (1 - e^2/4 - 3e^4/64 - 5e^6/256 - \\ \cdots)\varphi - (3e^2/8 + 3e^4/32 + \\ 45e^6/1024 + \cdots)\sin^2\varphi + \\ (15e^4/256 + 45e^6/1024 + \cdots)\sin^4\varphi - \\ (35e^6/3072 + \cdots)\sin^6\varphi + \cdots \end{bmatrix} \quad (34)$$

M = Distance on the meridian from parallel of false origin (4°N for NTM and 0° for UTM) to the parallel, φ_A of point.

φ_A = Latitude of the point

According to Manchuk (2009), M_o is computed using Equation (34) for φ_o, which is the latitude crossing the central meridian at the origin of the (*E, N*) coordinates. Equations (1) to (34) are used to develop programs which the transformation/conversion software normally apply during computation / conversion.

1.6 Properties/Characteristics of Nigeria (Modified) Transverse Mercator projection (NTM)

The NTM is a modified version of TM adopted for Nigeria. The modifications take care of the large expanse of the country which covers about l0° (i.e. 4°N - 14°N) latitude and 12° (i.e. 2° 30° - 14° 30°E) longitude. It is generally referred to as 3-belt system

(Omoigui, 1973 and Idowu, 2012). The characteristics of Nigeria (modified) Transverse Mercator Projection (NTM) as given by Uzodinma, *et al.* (2013) are:

1. NTM is a conformal projection
2. The country is divided into 3 belts each 4o wide (Figure 2).
3. The 3 belts are bounded in the north by the 14oNparallel and in the south by 4oN. Hence the false origin of northing is at latitude 4o N and False Northing, No = 0.000m (see Table 1).

Table 1: NTM Grid Parameters

Belt	Bounding Longitudes	Central Meridian (l_o)	False Easting of Central Meridian
West	2°30'E – 6°30'E	4°30' E	230738.266m E
Mid	6° 30' – 10°30'E	8° 30' E	670553.984m E
East	10°30' – 14°30'E	12° 30' E	1110369.702m E

Source: Uzodinma, et al (2013)

4. The scale factor at each central meridian is 0.99975.
5. A rectangular metric grid is superimposed on the three belts such that they intersect along the 9°N parallel.

According to Ufuah and Adesina (2005) and Eteje *et al.* (2018), the central meridians of the west and east belts are fixed respectively to be 439815.718 metres west and east of the central meridian of the mid belt along the 9°N parallel. The maximum angular distance of a point in a belt, from the central meridian of the belt, is 2°. In other words, each belt is 4° wide.

1.7 Properties/Characteristics of Universal Traverse Mercator (UTM) as Applied in Nigeria

Uzodinma *et al.* (2013) also gave the properties/characteristics of the UTM as applied in Nigeria as follow:

1. Nigeria is covered by zones 31, 32 and 33 of the UTM.
2. Each zone has its independent coordinate system with X-axis 500,000.0m west of the central meridian and Y-axis lying along the equator.

The UTM grid parameters are shown in table 2 as given by Uzodinma *et al.* (2013).

Table 2: UTM Grid Parameters

Zone	Bounding Longitudes	Central Meridian (l_o)	Grid Coord. of Central Meridian
31	0 °- 6°E	3°E	0.0m N, 500,000.0mE
32	6° – 12°E	9°E	0.0m N, 500,000.0mE
33	12° – 18°E	15°E	0.0m N, 500,000.0mE

Source: Uzodinma, et al (2013)

3. UTM in Nigeria is computed on the Clarke 1880 reference ellipsoid.

In the UTM, the maximum angular distance of a point in a belt, from the central meridian of the zone is 3º (Mugnier *et al.,* 2009). Thus, each zone is 6° wide. Its application is limited to between latitudes 84°N and 80°S as stated by Edan *et al.* (2014).

The properties/parameters of each of the plane rectangular systems, NTM and UTM and those of the datum in question (Minna datum) are applied during the conversion of the coordinates using the software. The parameters to apply in each plane rectangular

system depend on either the belt or the zone in which the positions are.

II. METHODOLOGY

The procedure for the application of the two software (AllTrans and Columbus software) for conversion between NTM and UTM in Minna datum requires the NTM coordinates be converted to geographic coordinates using equations (1) and (2), then the geographic coordinates are converted to UTM coordinates using equations (25) and (26). The same procedure is used when converting UTM coordinates to NTM positions (see figure 1).

2.1 Procedure for Application of AllTrans Software for Coordinates Conversion between NTM and UTM

The following steps are considered when converting positions from NTM to UTM:

1. Launch the software, displays as shown in Figure 2.
2. In Start Coordinate System, drop-down Area and select Nigeria. This will automatically display Minna (Clarke 1880 (RGS)) in the Geod Datum.

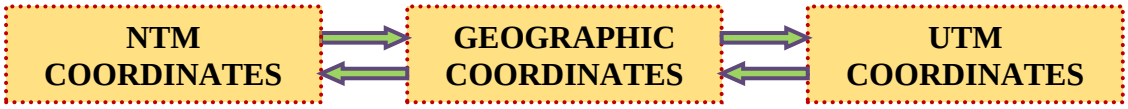

Fig. 1: Conversion between NTM and UTM Coordinates

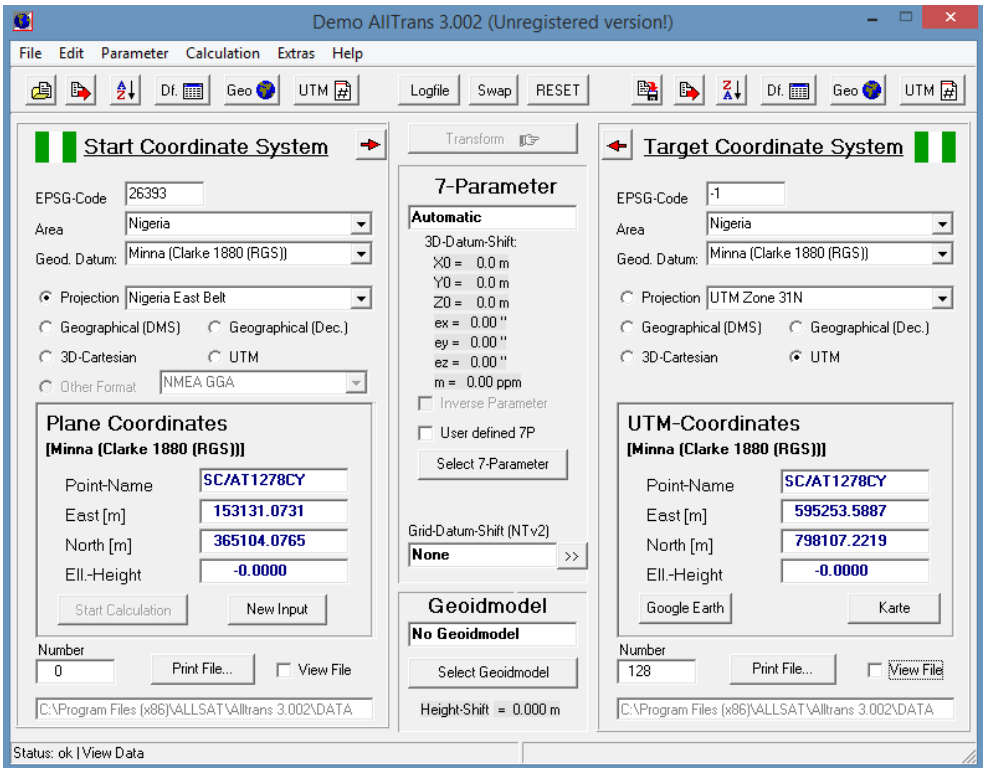

Fig. 2: Launched AllTrans Software

2.2 Procedure for Application of AllTrans Software for Coordinates Conversion between NTM and UTM

The following steps are considered when converting positions from NTM to UTM:

1. Launch the software, displays as shown in Figure 2.
2. In Start Coordinate System, drop-down Area and select Nigeria. This will automatically display Minna (Clarke 1880 (RGS)) in the Geod Datum.
3. Check Projection and select either west, mid or east belt, depending on the belt in which the positions to convert are.

4. In Target Coordinate System, drop-down Area and select Nigeria. This will also automatically display Minna (Clarke 1880 (RGS)) in the Geod Datum.

5. Check UTM and select either zone 31, 32 or 33, also depending on the zone in which the positions to convert are.

6. In Plane Coordinate, input the control ID and coordinates (northing and easting) accordingly one after the other.

7. Finally, click on Start Calculation at the bottom right-hand side of the software environment to convert and display the converted UTM coordinates. Note that at this step, the coordinates of a point are converted one after the other.

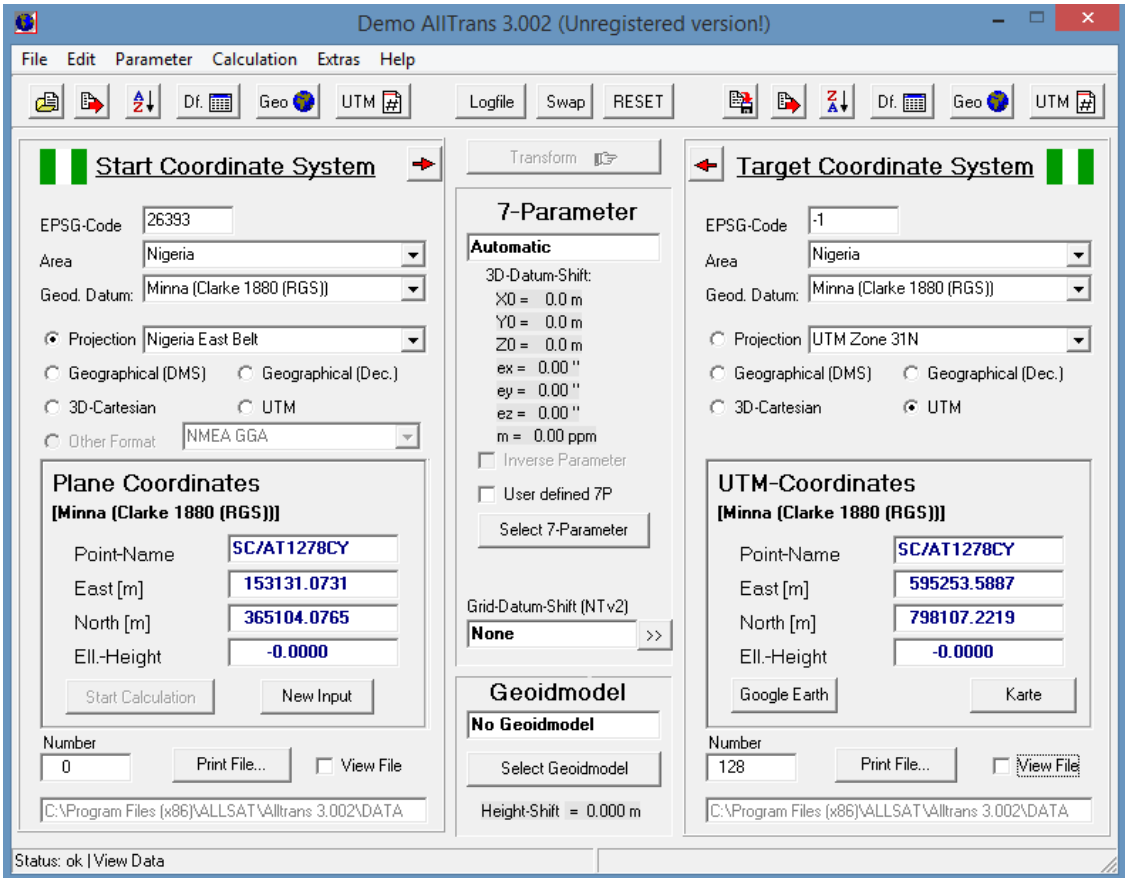

Fig. 2: Launched AllTrans Software

8. If the coordinates are many and they are to be converted at the same time, click the Parameter menu then, the Format of Data submenu to select State System. This will display the Start System Data Format dialog box. In the dialog box, click on Plan Coord tab and check/select data format of interest say Name, North, East and Height and click OK (see Figure 3).

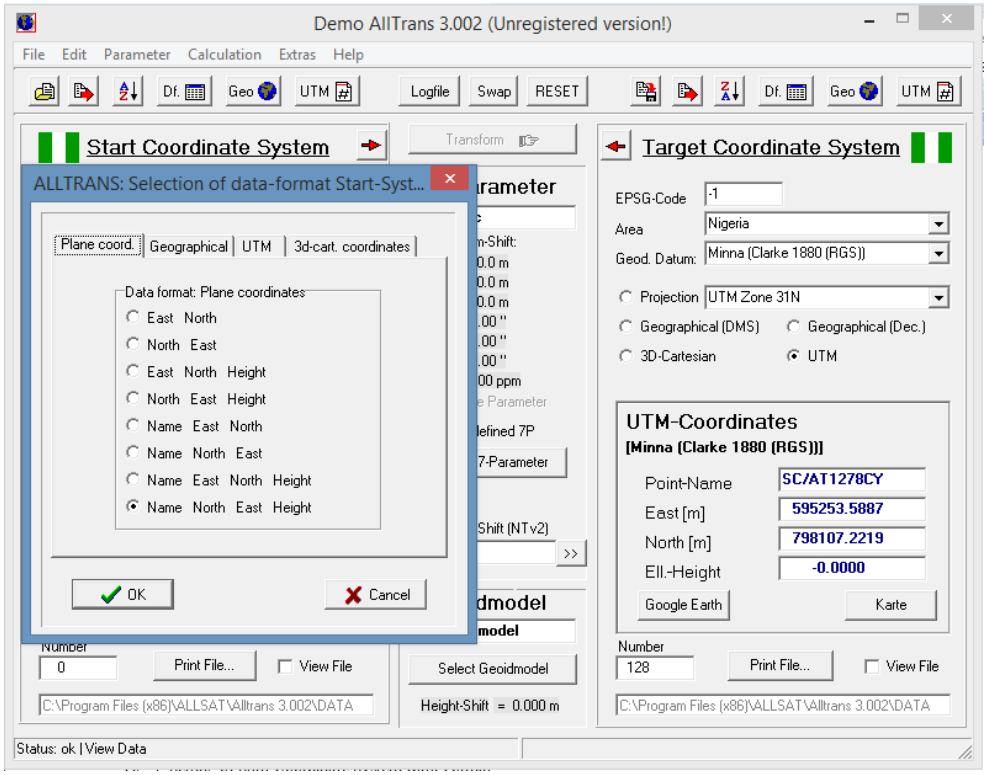

Fig. 3: Setting of Start Coordinate System Data Format

9. Also, set the Target Coordinate System Data Format. Click the Parameter menu then, the Format of Data submenu to select Target System. This will display the Target System Data Format dialog box. In the dialog box, click on UTM tab and check/select data format of interest say Name, North, East and Height and click OK (see Figure 4). Note that the Start and the Target Coordinate System data format must be the same.

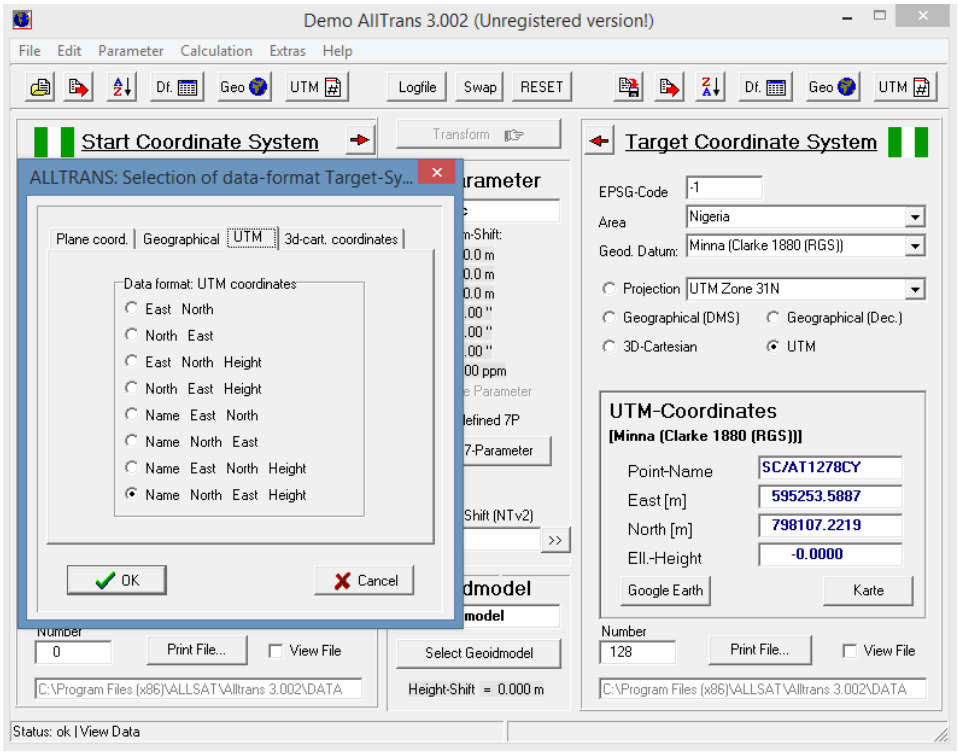

Fig. 4: Setting of Target Coordinate System Data Format

10. Type the input coordinates (NTM) in notepad in the order of the chosen data format and save the file on either Desktop or in Document.
11. Click on the File menu and select Open File (File Input) submenu. Navigate to where the saved input file is and import the NTM coordinates to the software environment.
12. Click on Start Calculation at the bottom left-hand side of the software to convert the NTM coordinates in the imported file.
13. Click on View File at the bottom right-hand side of the software to display the converted UTM coordinates.
14. Also, click on View File at the bottom left-hand side of the software to display the inputted NTM coordinates (See Figure 5).

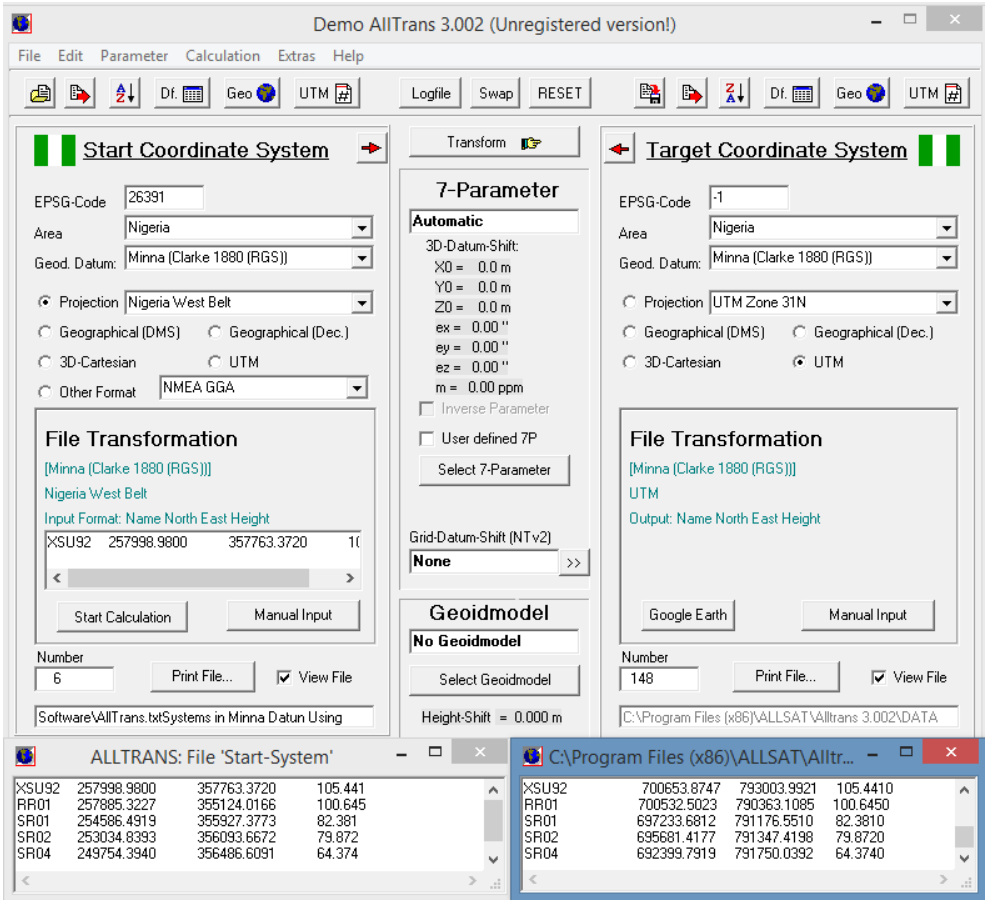

Fig. 5: Inputted NTM and Converted UTM Coordinates

To convert from UTM to MTN, the same procedure is used except for the following:

1. In step 3, the Start Coordinate System will be set to UTM and either zone 31, 32 or 33 will be selected, depending on the zone in which the UTM coordinates to convert are.
2. In step 5, check Projection and select either west, mid or east belt, depending on the belt in which the positions to convert are.
3. In step 6, in UTM Coordinate, input the control number and the UTM coordinates (northing and easting) accordingly one after the other.
4. In step 6, click on Start Calculation to convert and display the converted NTM coordinates at the bottom right-hand side of the software environment.
5. In steps 8 and 9, set the Start (input) and the Target (output) Coordinate Systems data formats to UTM and NTM respectively. And they must be the same.

6. In step 12, also click on Start Calculation at the bottom left-hand side of the software to convert the UTM coordinates in the imported file.
7. In steps 13 and 14, click on View at the bottom right and left-hand sides to respectively display the converted NTM and the inputted UTM coordinates.

2.3 Procedure for Application of Columbus Software for Coordinates Conversion between NTM and UTM

The conversion of coordinates between two rectangular systems using Columbus software, requires the rectangular coordinates be converted to geographic positions then, the geographic positions are re-entered into the software and converted to rectangular coordinates of interest. Columbus is not like AllTrans software that does the conversion directly. The following steps are considered when converting positions from NTM to UTM:

1. Launch the software.
2. Click on the File menu to select New as shown in Figure 6. This will display a new working environment.

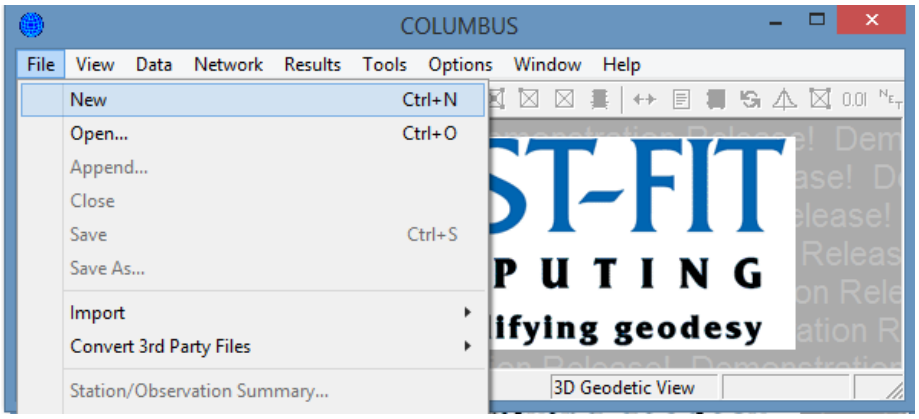

Fig. 6: Creating New Working Environment

3. Click on Options menu to select Datum submenu. This will display Select a Datum dialog box. In the dialog box, select Clarke 1880 and click OK (see Figure 7).

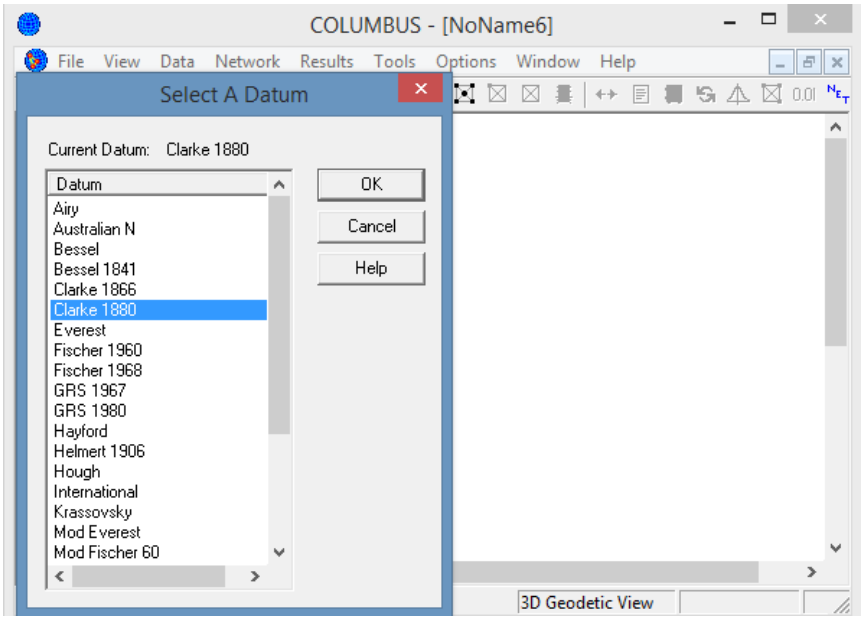

Fig. 7: Selection of Datum (Ellipsoid)

4. Also, click on the Options menu to select Unit submenu. This will display Linear and Angular Units dialog box. In the dialog box, check Metres in Linear Units, Degrees in Angular Units and DD.MMSSssss (Degree Minute and Second) in DMS or GMS Input and click OK (see Figure 8).

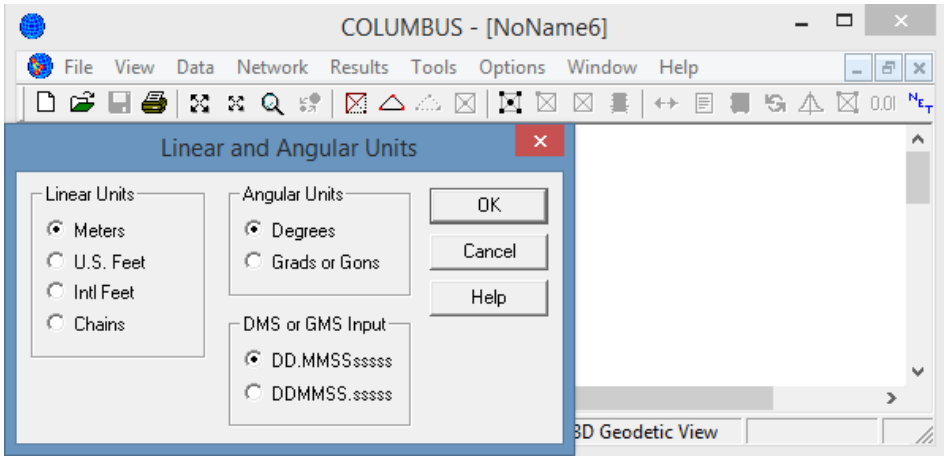

Fig. 8: Linear and Angular Units Settings

5. To set/enter the NTM belt parameters in which the positions to convert are, click on Options menu to select Projection submenu. In the Projection submenu, select State Plane Zones to display Select/Setup The Current Projection Zone dialog box. In the dialog box, select User Define (UD Traverse Mercator, TM) (see Figure 9) and click OK to display Setup Traverse Mercator Projection dialog box. In the dialog box, enter the belt parameters in which the coordinates to convert are. Enter the following parameters for the Nigeria West belt given in the first row of Table 1 as shown in Figure 10.

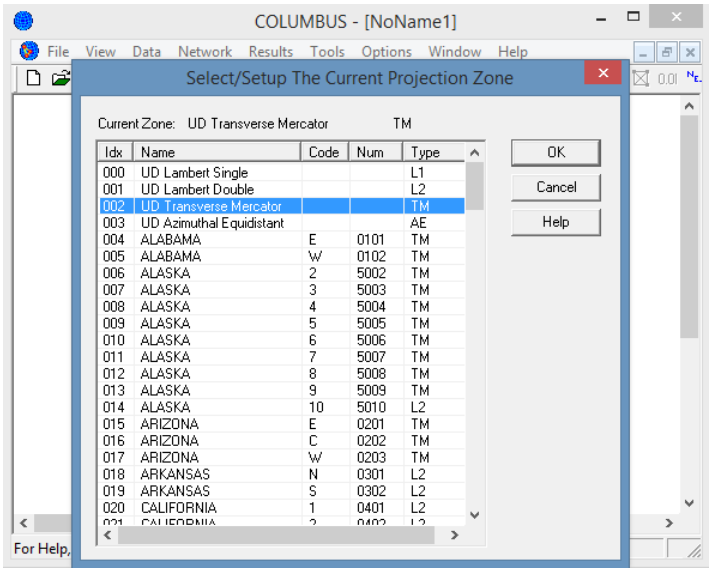

Fig. 9: Selection of Current Traverse Mercator Belt

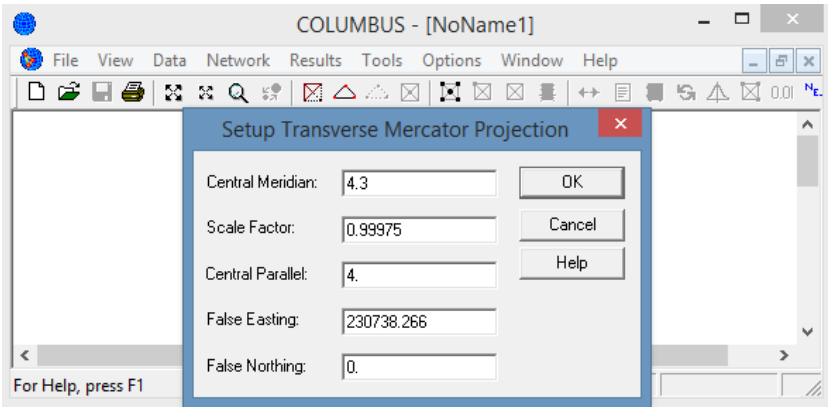

Fig. 10: Entering of the Positions Belt Parameters (Nigeria West Belt Parameters)

6. To set/enter the UTM zone parameters in which the positions to convert are, click on Options menu to select Projection submenu. In the Projection submenu, select UTM Zone Setup to display UTM or TM Zone Setup dialog box. In the dialog box, select the zone in which the coordinates to convert are and click OK. Here, zone 31 is selected as shown in Figure 11. Note that the selection of a zone will automatically update the other fields of the dialog box.

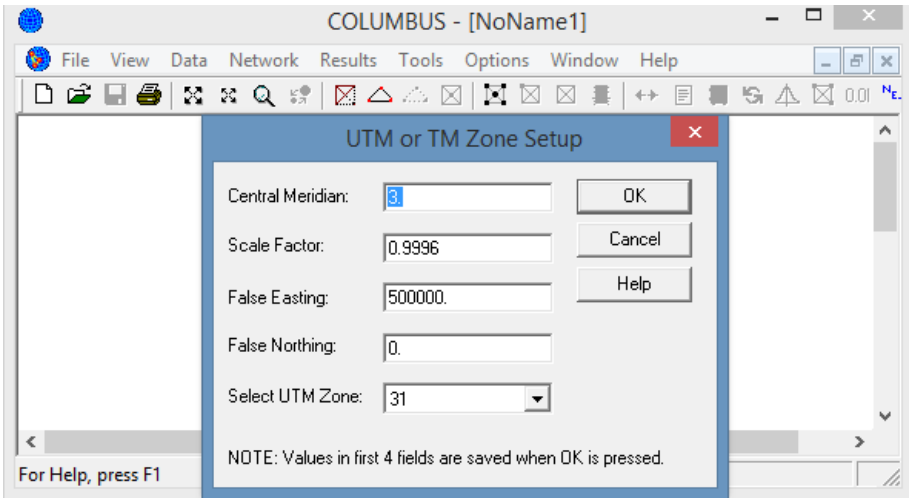

Fig. 11: Entering of the Positions Zone Parameters (Zone 31 Parameters)

7. Having done with the necessary settings, click on the Data menu and select Stations submenu to display Add or Modify Station Data dialog box. In the dialog box, click on State Plane to enter the NTM coordinates. Also, click on Add 25 Rows at the top right-hand side of the dialog box to display the spreadsheet in which the positions information will be entered. Enter the stations' IDs/Numbers, Northing and Easting coordinates of the points and click Keep and Exit tab at the bottom left-hand side of the dialog box (see Figure 12). This will exit the dialog box and plot the points/stations in the software environment (see Figure 13).

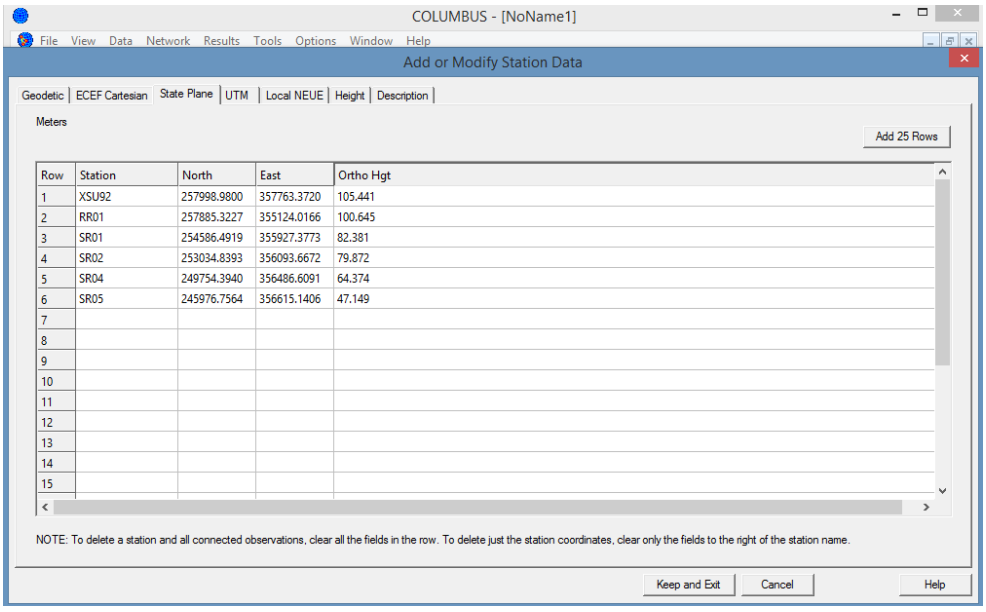

Fig. 12: Entering of the NTM Coordinates

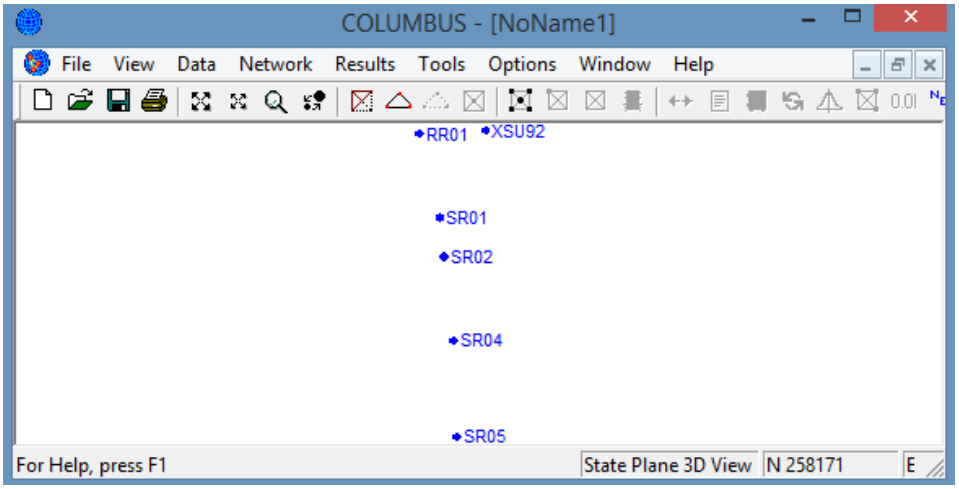

Fig. 13: Plotted UTM Points in the Software Environment

8. To convert the NTM coordinates to geodetic positions, click on the Tools menu to select Transformation submenu. In the Transformation submenu, select State Plane to Geodetic to display State Plane to Geodetic Zone UD Traverse Mercator dialog box. In the dialog box, click on Compute at the bottom left hand side to display Select Station to Transform dialog box. In the displayed dialog box, click Select All at the middle right-hand side and click OK at the top right-hand side (see Figure 14). The converted geodetic coordinates are displayed in the State Plane to Geodetic Zone: UD Traverse Mercator dialog box. Also, see Figure 15.

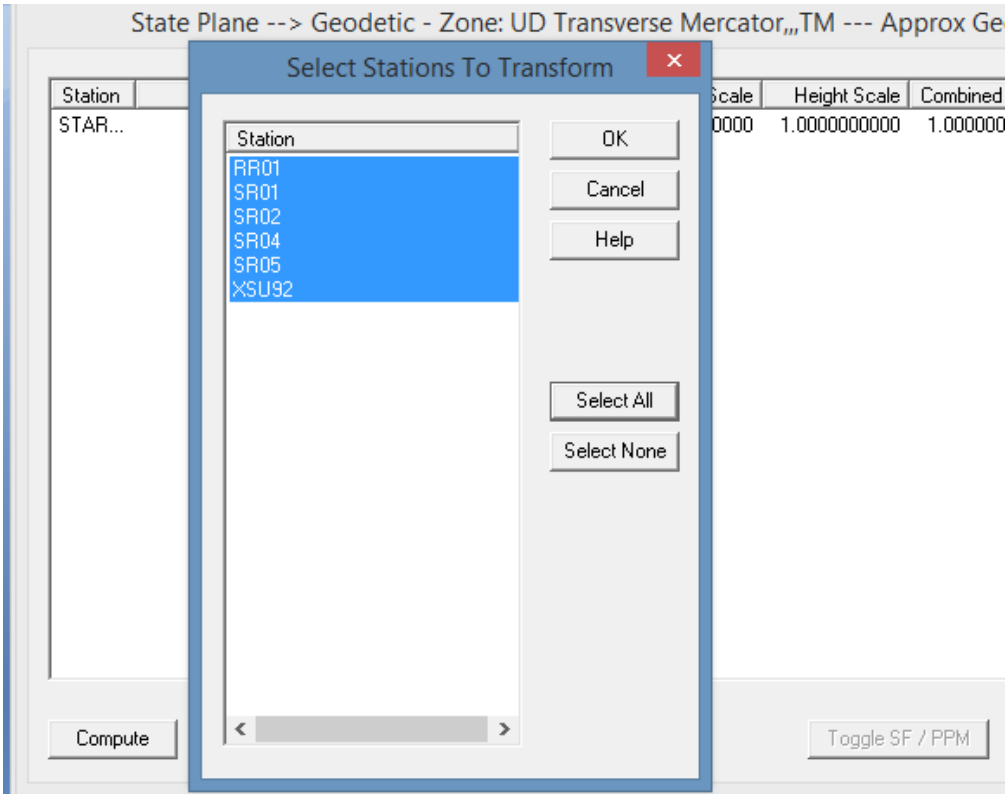

Fig. 14: Selected Points/Stations

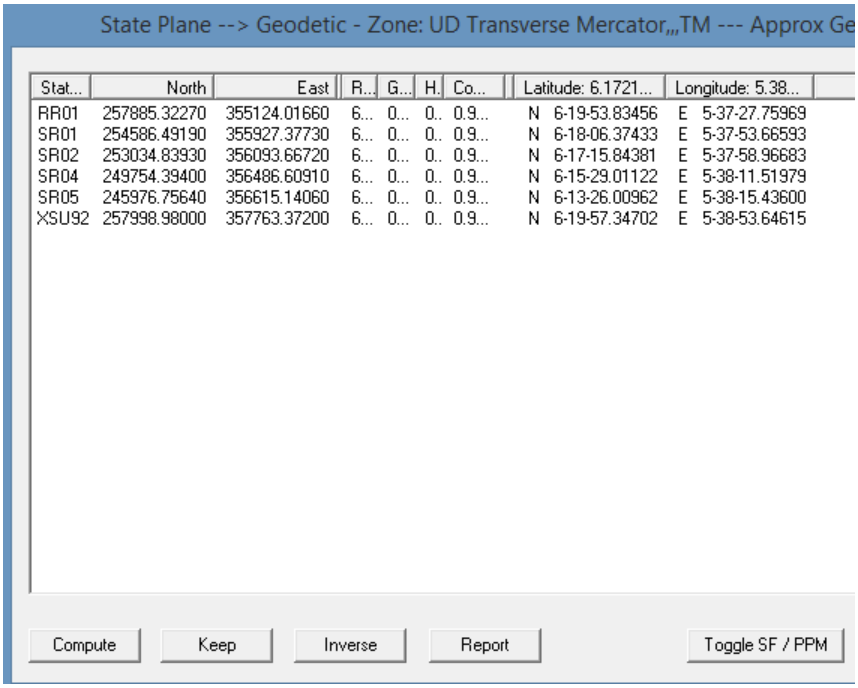

Fig. 15: Converted Geodetic Coordinates

9. To report the converted geographic coordinates, click on Report at the bottom left-hand side of the State Plane to Geodetic Zone: UD Traverse Mercator dialog box to save the converted coordinates/processing report on either Desktop or in the Documents folder. The processing report is given in both Excel and Notepad. Figure 16 shows the Notepad processing report.

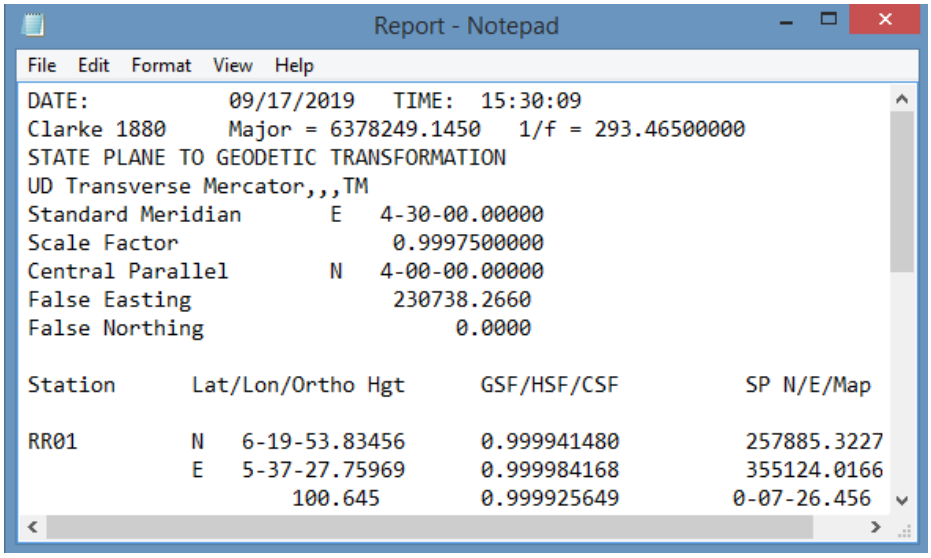

Fig. 16: Processing Report for Converted Geodetic Coordinates in Notepad

10. Having converted the NTM coordinates to geographic positions then, repeat step 7 to enter the converted geodetic coordinates in the Geodetic tab of the Add or Modify Station Data dialog box.

11. Repeat step 8 to convert the geodetic coordinates to UTM positions. In the Transformation submenu, select Geodetic to UTM.

12. Also, repeat step 9 to report the converted UTM coordinates (see Figure 17).

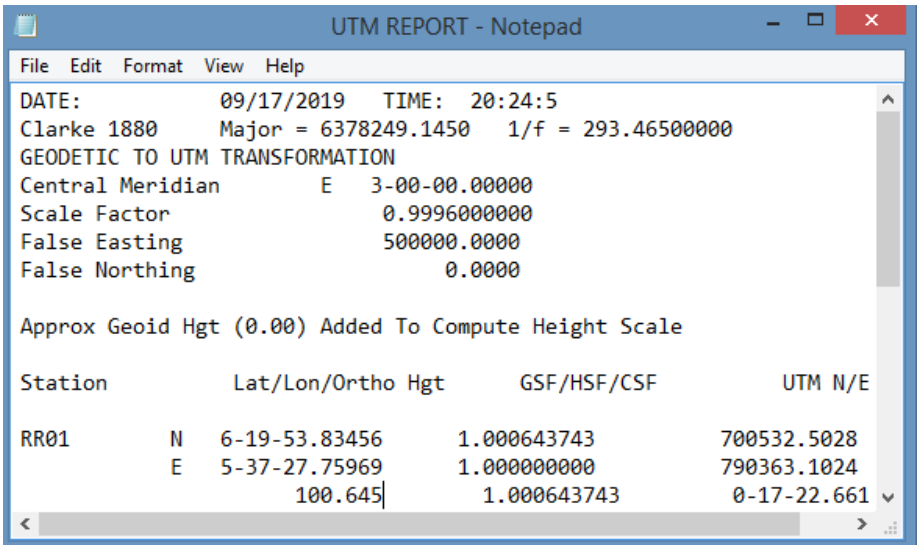

Fig. 17: Processing Report for Converted UTM Coordinates in Notepad

To convert from UTM to NTM with Columbus software, the same procedure is used except for the following:

1. In step 7, enter the UTM coordinates in the Add or Modify Station Data dialog box.
2. In step 8, select UTM to Geodetic in the Transformation submenu.
3. Having converted the UTM coordinates to geodetic positions, repeat step 7 to enter the converted geodetic coordinates in the Geodetic tab of the Add or Modify Station Data dialog box.
4. Repeat step 8 to convert the geographic coordinates to NTM positions.
5. Also, repeat step 9 to report the converted NTM coordinates.

III. CONCLUSIONS AND RECOMMENDATIONS

Having given detailed procedures for the use of AllTrans and Columbus software for the conversion of coordinates between NTM and UTM systems, the following conclusions and recommendations were made:

1. For effective application of the two software, considering the enumerated steps to be considered, the belt, as well as the zone in which the positions to convert are must be identified before the conversion process. This will enable the right, as well as the correct belt and zone parameters, be entered in the software.
2. The Minna datum, as well as Clarke 1880 ellipsoid parameters, should be correctly inputted into the software as the conversion is within Minna datum only. Thus, the Clarke 1880 ellipsoid is common to both coordinate systems in this regard.
3. The Edo State branch of the institution (NIS) should get the full and the latest version of the software.
4. There should also be a lecture for the practical demonstration of the detailed procedures.

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